Investigative Report

Test Cell 831 Druck Pressure Transducer Failure on March 25, 2003

May 5, 2003

Issued By
National Aeronautics and Space Administration
Johnson Space Center
White Sands Test Facility
Laboratories Office

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Abstract

At approximately 19:00 on March 25, 2003, during life cycle testing of the Improved Pilot Operating Valve (IPOV) in Nitrogen Tetroxide (NTO) in Test Cell 831, an explosion was heard in the Hazardous Fluids Test Area (HFTA) Control Room. The NTO release in Test Cell 831 obscured video camera visibility inside the test cell. The emergency shutdown procedures were activated to secure the test cell and the HFTA air handlers were shutdown due to the extent of the NTO release. An odor of NTO was detected in the High Pressure Test Area (HPTA). No personnel were injured. During subsequent investigation, with personnel protected by Totally Encapsulated Suits (TES), it was determined that the pressure transducer PT-8OX-BB322 had catastrophically failed. This pressure transducer was located at the inlet of the IPOV and experienced dynamic pressure fluctuations as the IPOV opened and closed for each 80 ms flow duration. An investigation commenced on the morning of March 26, 2003.

The investigation involved securing the damaged hardware, review of test data, failure analysis of the failed hardware, investigation into the design and construction of the failed pressure transducer, review of historical data on the pressure transducer, chemical analysis of residue in the area of the failure, and comparison of this residue with the products of silicone oil exposed to NTO in a “beaker test”.

The pressure transducer is a Druck Model PDCR 130/W/C, manufacturer’s serial number 460553, and WSTF ECN 893800. The item was purchased in 1994, used in the 300 area in helium, and then in the HFTA with oxidizer.

The pressure transducer failed at a welded connection between the port housing and the sensor housing. The pressure to fail this welded connection was calculated to be 12,700 psi. The pressure transducer is connected by a ¼ X 0.035 wall 300 series stainless steel tubing to ¾ X 0.035 inch wall 300 series stainless steel tubing. The thrust from the failed pressure transducer resulting in also failing the ¼ inch tubing close to the ¾ inch tubing. The ¾ inch tubing showed no sign of yielding due to pressure, indicating that the system pressure did not exceed the calculated 3,400 psi required to yield this tubing. Failure appears to be the result of extremely rapid over-pressurization inside the pressure transducer.

The Druck pressure transducer has a silicon sensor and a 316 stainless steel isolation diaphragm between the sensor and the test media. The ~0.78 ml volume between the isolation diaphragm and the sensor is filled with DC550 poly(methylphenylsiloxane) silicone oil. Poly(methylphenylsiloxane) reacts in a non-violent fashion with NTO to form nitro-substituted phenols, which tend to be shock and friction sensitive. Poly(dimethylsiloxane) silicone oil does not appear to be effected by NTO. Evidence of 2,4-dinitrophenol and 2,4,6-trinitrophenol (picric acid) was found on the failed pressure transducer parts, support bracket, and diluted in the supply of NTO downstream of the IPOV.

Recommendations include discontinued use of isolation diaphragm style, silicone oil filled pressure transducers in NTO systems and reconsideration of the HFTA wind corridor. Use in other media systems should be based on single point failure analysis of the isolation diaphragm with acceptable risk based on media compatibility and contamination to the system and test hardware.

Contents

1.0 Introduction

The Improved Pilot Operating Valve (IPOV) was being tested in the Hazardous Fluids Test Area (HFTA) Test Cell 831 to validate Improved Pilot Operating Valve (IPOV) modifications. The IPOV inlet is pressurized at 276 psia from one tank of Nitrogen Tetroxide (NTO) and flows to a second tank. The system is designed to allow flow from or into each of the NTO tanks. The IPOV flow duration is 80 ms and a maximum flow of 1.91 lb/sec is achieved. A Druck PDCR 130/W/C pressure transducer is used to monitor the IPOV inlet pressure. Approximately 36,000 test cycles had been performed.

At approximately 19:00 on March 25, 2003, an explosion was heard in the HFTA Control Room. The NTO release in Test Cell 831 resulted in obscured video camera visibility of the test cell. The emergency shutdown procedures were activated to secure the test cell and the HFTA air handlers were shutdown. An odor of NTO was later detected in the High Pressure Test Area (HPTA). A lower level odor was detected in the HFTA Control Room. No personnel were injured. During subsequent investigation, with personnel protected by Totally Encapsulated Suits (TES), it was determined that the pressure transducer PT-8OX-BB322 had catastrophically failed. Figure 1 shows the area of the pressure transducer failure and the approximate previous location of the manifold and pressure transducer. An investigation commenced on the morning of March 26, 2003. DR 2-LAB-030657 and Close Call 03-025 were initiated for this failure.

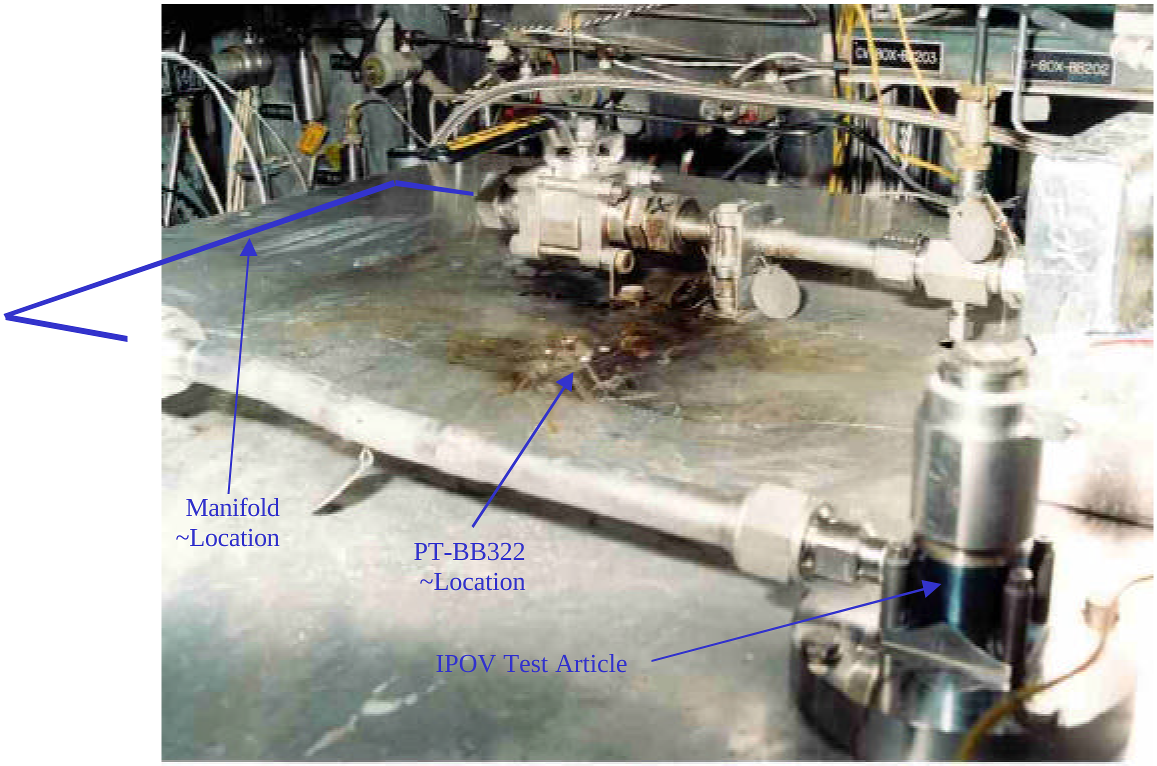


Figure 1: Location of Failed Pressure Transducer in Test Cell 831

2.0 Objective

There are three objectives of this investigation.
1) Understand the cause of the pressure transducer failure.
2) Review the wind corridor based on NTO vapor entering the HPTA.
3) Make recommendations based on the investigation.

In addition, the impact to testing and activity in Test Cell 831 were to be minimized.

3.0 Background

Initial inspection of the failed pressure transducer indicated pressure failure. There are several potential causes for this type of pressure failure; including over-pressurization, inadequate design, or cyclic fatigue at a highly stressed location, that were considered. Pressure data at this location was limited to output from the failed transducer. Analysis of the fracture surfaces would help determine if the failure were cyclic fatigue or ductile failure from a single over-load condition. Examination of the nearby system tubing would indicate if pressures in the system close to the pressure transducer had experienced pressure that exceeded the tubing yield strength.

4.0 Approach

The test system had been secured after the failure to stop the release of NTO, halt testing, and safe the system for later entry. The pressure transducer port housing and approximately ¾ of the diaphragm were located shortly after the failure and had been decontaminated. Most of the members of the investigation team met with test personnel to determine the best course of action. The course of action established at that meeting follows.

The following course of action was proposed and agreed upon by those at the meeting and was then approved by Labs management. The makeup of the team had not been finalized at this point in time. The final team members are shown on the signature page of this report. The name in parenthesis after each item will complete the item. (All of these items have been completed.)

a) Secure the broken hardware (currently in the oxidizer decon station) (Don Saunders)
b) Secure test and wind condition data files - copy of files to John Anderson (Dave Hicks)
c) Using TES, enter Test Cell 831, take interscan measurements and ensure area is clear (or safe) prior to unprotected entry (Mike Reynolds, Mike. Mannon and Don Saunders)
d) Search for all debris and decon and secure the pieces (Mike Mannon, and Don Saunders)
e) Using a micrometer, measure the outside diameter of the 3/4 inch tubing which attaches to the test article to determine if the tubing was deformed by

"water hammer" - information to John Anderson (Mike Mannon, and Don Saunders)

f) Document the broken pieces with photographs (Mike Reynolds)
g) Write a Close Call for the oxidizer fumes inside the HPTA (Mike Reynolds)
h) Initiate a DR to document the test system damage and record the results of the investigation (Mike Reynolds)
i) Complete a NASA form 1627 for the damage to the test system, request made by Don Hall after the meeting (Mike Reynolds)
j) Using a micrometer, measure the inside diameter of the broken manifold that forms the flow path for the oxidizer release (Mike Mannon and Don Saunders)
k) Calculate the quantity of oxidizer that would be released through the broken manifold based on a time duration of 2 seconds from the event to closing the isolation valve(s) (John Anderson)
l) Locate make, model number, ECN, and range information for the failed pressure transducer and provide to John Anderson (Don Saunders)
m) Consider appropriate wind corridor for when testing resumes (Alan Porter and Todd Kaufman)

After management approval of the proposed course of action, the investigation began by securing as much of the failed hardware as possible. The primary evidence available were the failed pressure transducer parts, test system in close proximity to the failure, test data, wind data, and information from the test team. This evidence was examined, chemical and metallurgical analysis was performed, and calculations were performed. In addition, a similar Druck pressure transducer, that was previously sectioned for another issue, was examined, manufacturer's specifications were reviewed, and discussions were held with the manufacturer.

5.0 Investigation and Analysis

5.1 Examination of Pressure Transducer and System

The pressure transducer failed at a welded connection between the port housing and the sensor housing (see Figure 2). The weld appears to be an electron beam weld (EBW) butt weld configuration and failure is from longitudinal stress in the weld fusion zone. The pressure to fail this welded connection was calculated to be 12,700 psi (reference calculation JCA-1780). The ¼ X 0.035 wall 300 series stainless steel tubing connecting the pressure transducer to the ¾ X 0.035 inch wall 300 series stainless steel manifold tubing failed close to the larger tubing. The ¼-inch tubing was significantly deformed and damage appeared to be from thrust generated when the pressure transducer failed. Based on measuring the outside diameter in several locations, the ¾-inch tubing showed no sign of yielding due to pressure. This indicates that the system pressure did not exceed the calculated 3,400 psi required to yield this tubing (reference calculation JCA-1777). The failed diaphragm has a small diameter central area that is bulged and ruptured, which matches the inlet port flow passage diameter (see Figure 3). The calculated pressure to burst the diaphragm when supported at the port diameter is ~4,000 psi (reference calculation JCA-1784). Based on these observations, the Failure appears to be the result of extremely rapid over-pressurization inside the pressure transducer that first exceeded the ~4,000 psi diaphragm burst pressure. Flow through the 0.157 inch port flow diameter was inadequate to relieve the over-pressure thus enabling the pressure to reach the ~12,700 psi housing burst pressure. After burst, sufficient thrust was achieved to deform and then fail the ¼-inch pressure transducer connecting tubing. The sensor location of the pressure transducer is shown in Figure 4. Note the oily residue seen in this photo.

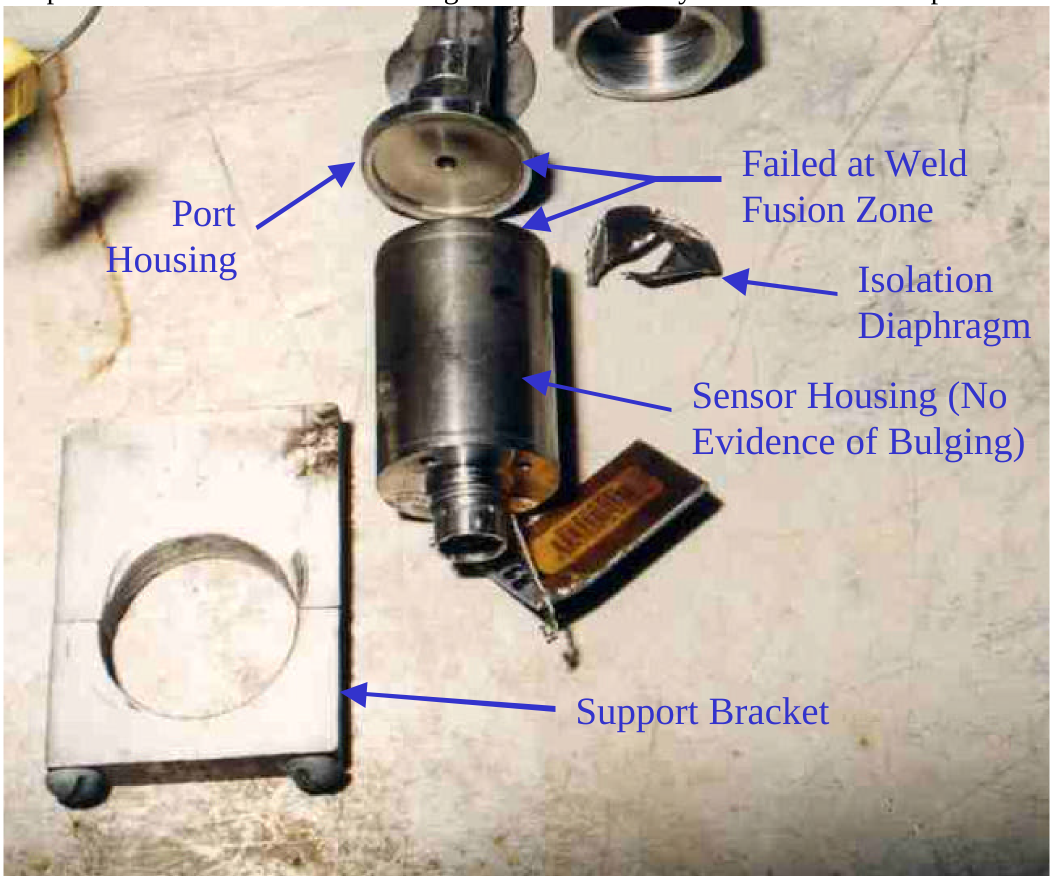


Figure 2: Failed Druck PDCR 130/W/C Pressure Transducer

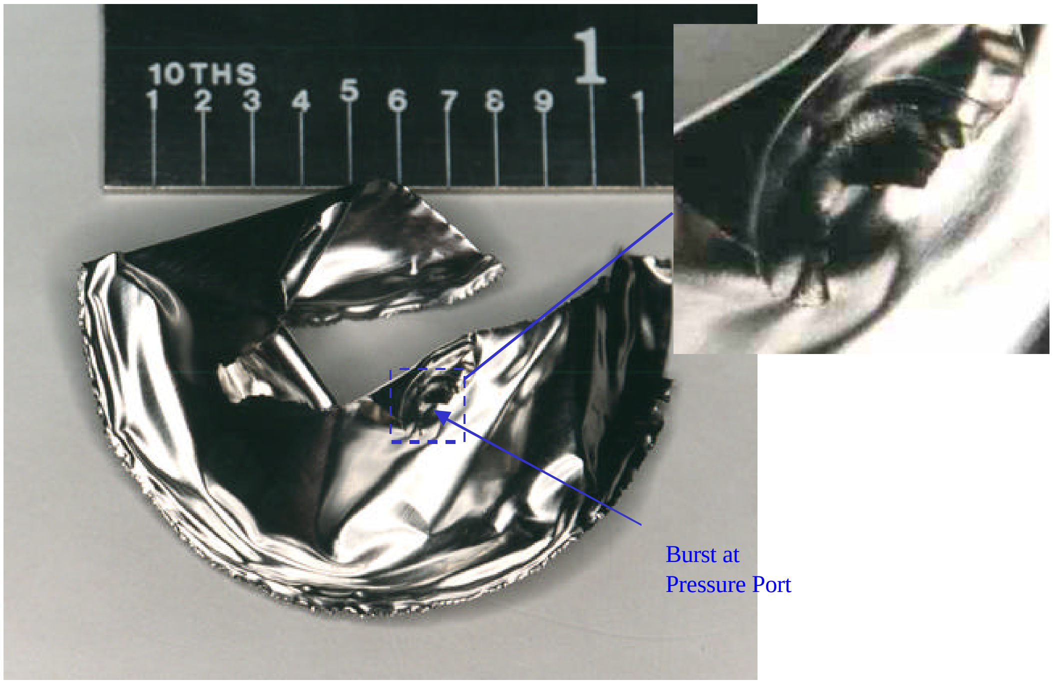
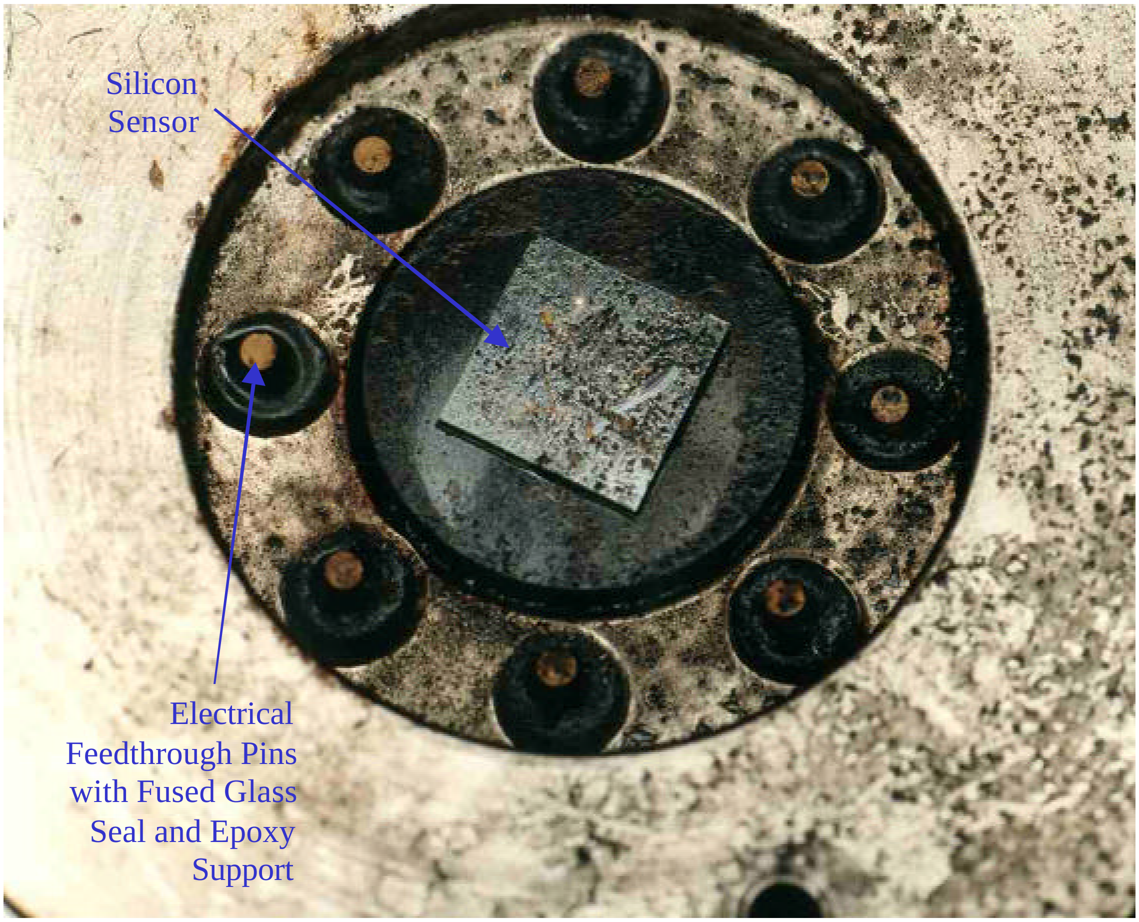


Figure 3: Failed Isolation Diaphragm

Figure 4: Failed Transducer Sensor



5.2 Pressure Transducer History

The pressure transducer is a Druck Model PDCR 130/W/C, manufacturer's serial number 460553, and WSTF ECN 893800. The original ECN was 892988. When this ECN tag was lost, ECN 893800 was assigned. The item was purchased in 1994, first used in the 300 area with helium, and then in the HFTA with oxidizer. One in-place calibration in March 19, 1996 noted the transducer was out of tolerance, but other calibrations did not note any problems meeting the manufacturer's specifications.

5.3 Druck Pressure Transducer Design and Specification Review

The Druck PDCR 130 pressure transducers utilize a silicon sensor that connects to the electronics through gold-plated feed-throughs that are sealed using fused glass and supported with epoxy. Very thin wires connect between the sensor and the feed-throughs. For the basic PDCR 130 pressure transducer, the media pressure acts directly on the silicon sensor. A option, designed by "/W", includes an isolation diaphragm that separates the media from the silicon sensor and is required for media that would not be compatible with the sensor or that is conductive. Silicone oil fills the volume between the isolation diaphragm and the sensor and transmits the media pressure to the sensor. The isolation diaphragm acts as a barrier membrane.

The current PDCR 130 Series specification, labeled as USPDCR130 – 10/93,was downloaded from the Druck.com USA website on April 8, 2003. The specification states that for the 900 to 10000 psi range PDCR/W pressure transducers, the range can be exceeded by 2 times (2,000 psi for the failed unit) causing negligible calibration change. The material in contact with the pressure media is stated as 316 stainless steel. The presence of silicone oil between the isolation diaphragm and the sensor is not mentioned in the specification. Based on an e-mail, from Stephen Sajben, Western Region Manager, GE Druck, dated April 22, 2003, Druck can substitute Halocarbon 4.2 for the silicone oil. This option is not listed in the specification but can be specified during procurement.

It should be noted that other manufacturers supply pressure transducers that have the same basic design as the failed item. Based on a limited review of manufacturers, specifications for pressure transducers generally do not contain reference to the type of oil fill used. Pressure transducers that utilize a silicon sensor quite often include an isolation diaphragm with an oil fill. Specifications for these transducers may state "silicon pressure sensor", "silicon technology", or list the strain gage type as "semi conductor".

5.4 Test Data Analysis

The test data was analyzed to determine the pressure that PT-8OX-BB322 experienced during the IPOV testing. Due to the location of the pressure transducer in the inlet of the IPOV, pressure spikes occur due to "water hammer". The failed pressure transducer was the only measurement of the inlet pressure. The high speed data was stored at a 10 kHz data rate (sampled every 100 μsec) and the slow speed data was stored at a 12.5 Hz data rate (sampled every 80 msec). The high speed data time is recorded without a time stamp and is simply an elapsed time with a window of 150 ms for each test cycle. Each test cycle consists of an 80 ms flow duration followed by a 960 ms delay before the next cycle begins for a cycle frequency of 1.04 seconds.

The high speed data from PT-BB322, prior to the time when PT-BB322 ceased to provide output data, was analyzed to determine the pressure that this portion of the system was subjected to. Figure 5 shows a typical pressure trace. The data indicates that the dynamic pressure exceeded the 0 to 1,000 psia scaling, resulting in clipped data.

Figure 6 has an expanded time scale during the peak pressure. Extrapolation of the leading and trailing edges of the trace was used to approximate the peak pressure at 1,380 psia. Future testing should use a transducer with appropriate range (0 to 1,500 or 0 to 2,000 psia) and scaling. Test system modification is being considered to limit peak pressure but the first runs are planned with existing configuration to determine the magnitude of the peak pressure.

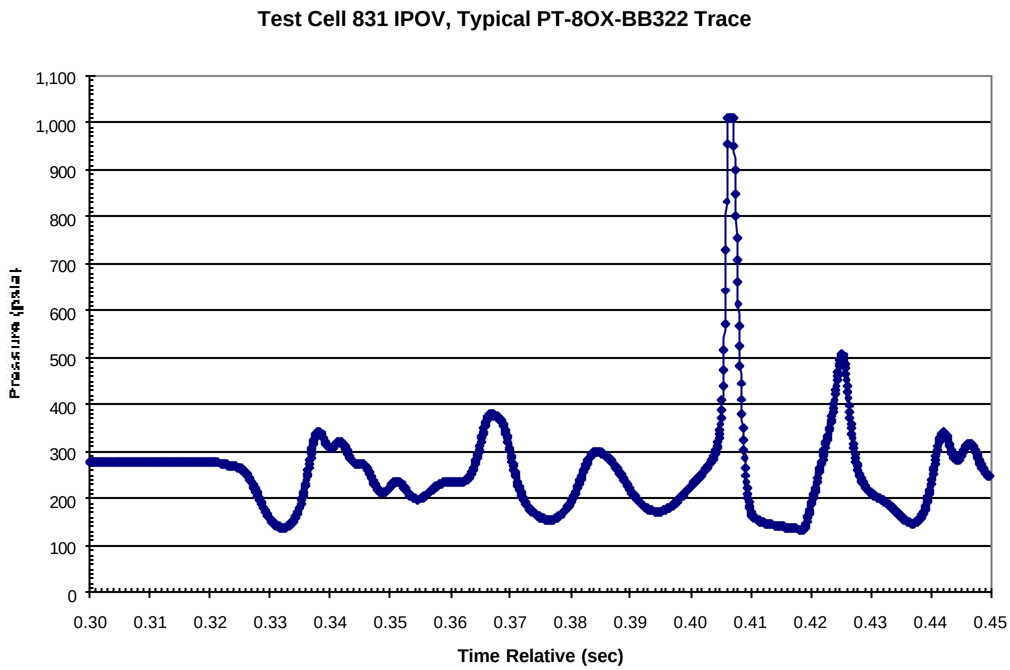


Figure 5: IPOV Inlet Pressure Measured by PT-BB322 Prior to Failure

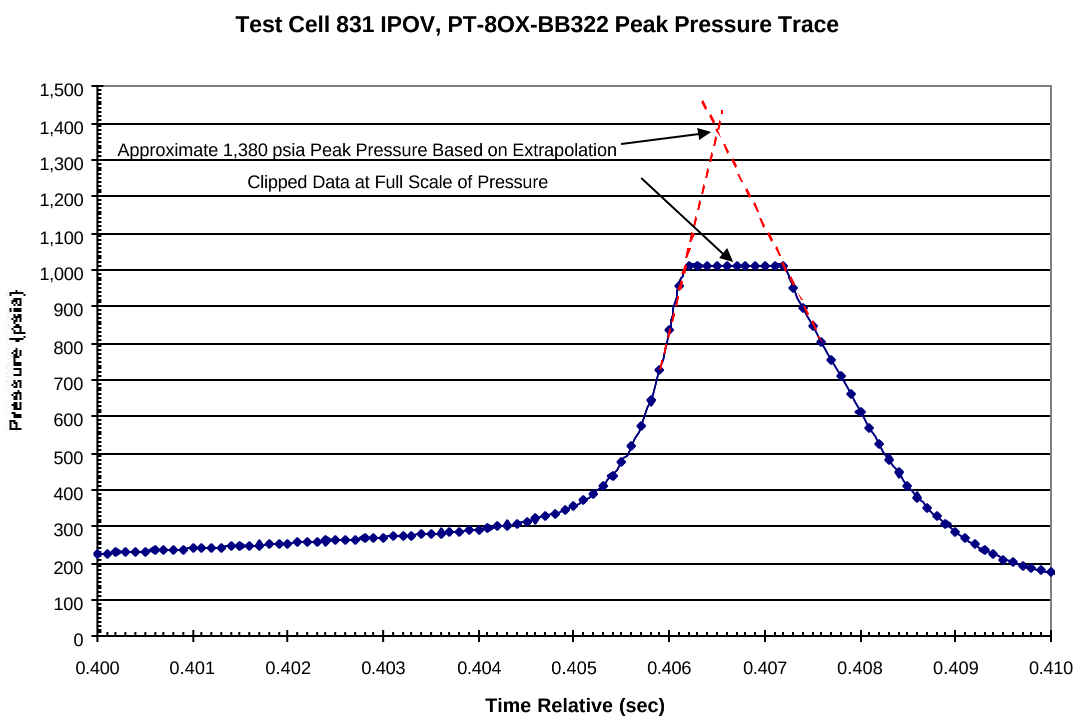


Figure 6: IPOV Inlet Pressure Measured by PT-BB322 Prior to Failure, Expanded Time Scale

The slow speed data for PT-BB322 and FM-BB325 was analyzed to determine when PT-322 no longer responded to the IPOV inlet pressure and the time delay before failure. At ~28 seconds after the test series began, the output from PT-BB322 shows a dramatic change and loss of response. At ~1,369 seconds after the test series began, FM-BB325 indicates a flow rate of ~1 lb/sec during the zero flow portion of the IPOV test cycle, indicating external leakage. Safing of the test system is observed ~7 seconds later based on the decreased flow rate after isolation valve closure and discontinuation of the test cycles. Based on this information, the time between PT-BB322 sensor failure and catastrophic pressure transducer housing failure was 1,341 seconds or 22.4 minutes. The real time output for PT-BB322 is a digital readout on a computer monitor. The loss of the pressure transducer output was not observed until later data analysis. Based on a flowrate of 1.05 lb/sec when the IPOV was no longer flowing, 7.3 seconds until system shutdown, and the data recorded during system venting through the failed ¼-inch line, the NTO loss during the failure was ~9.0 lbs or 2.8 liters.

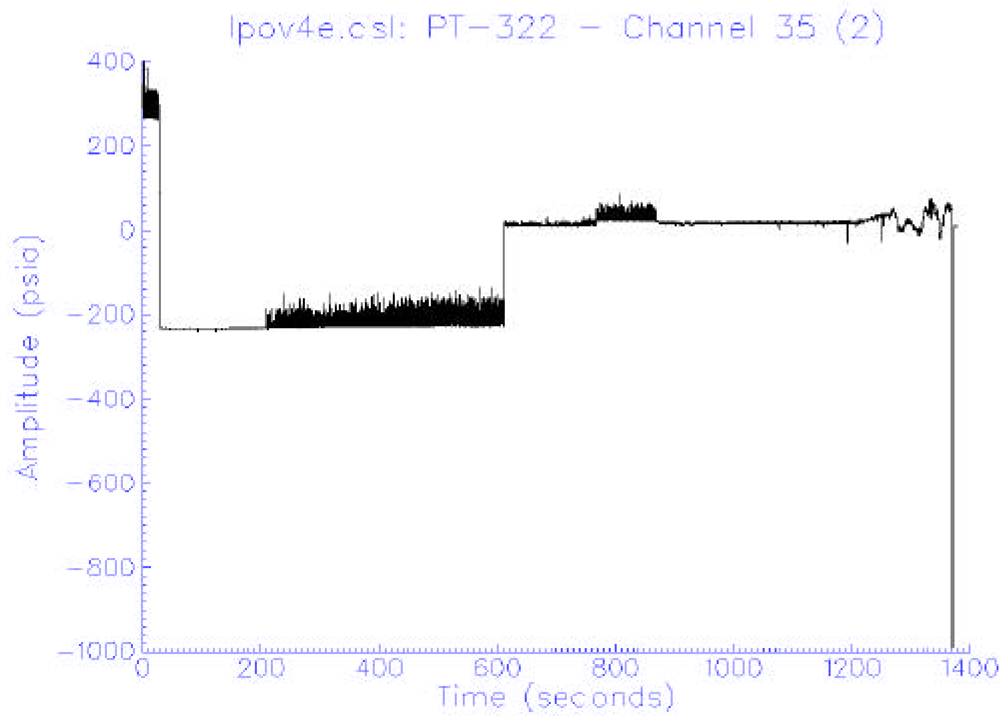


Figure 7: PT-BB322 Output Showing Loss of Function at ~28 Seconds

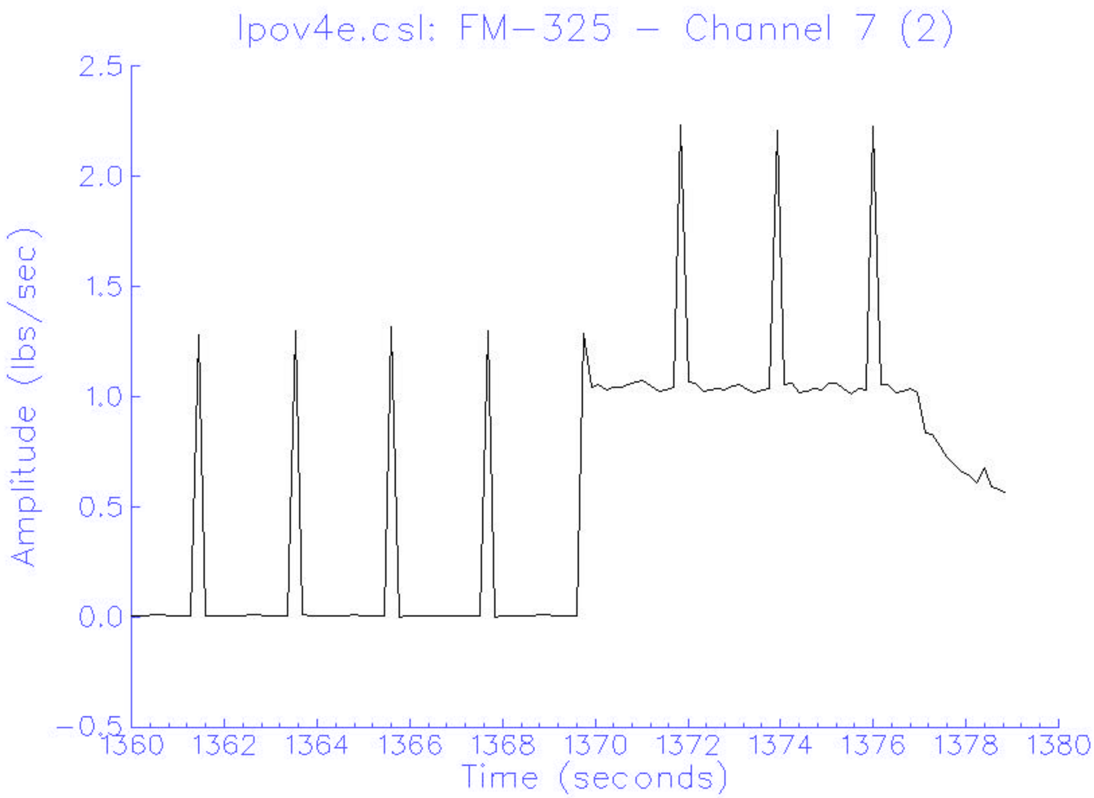


Figure 8: FM-BB325 Output Showing Increased flow at Failure and System Safing

5.5 Chemical Analysis

The failed pressure transducer housing and support bracket had a dark residue. These were submitted to the Chemistry Lab under LWO 701107 for analysis of the residue and silicone oil was found. This silicone oil was similar to a sample of Aldrich poly(methylphenylsiloxane) (PMPS) 510® fluid maintained in the Chemistry Lab. The "510" designation is a registered trademark of Dow Corning Corporation. A beaker test was performed with the 510® silicone oil in NTO under LWO 701137. The silicone oil reacted with the NTO and the formation of bubbles was noted. A brown residue from this beaker test was analyzed by Fourier Transform-Infrared (FT-IR) microscopy and found to be 2,4-dinitrophenol, which is a shock sensitive substance similar to picric acid. The dark residue from the pressure transducer housing and support bracket also contained 2,4-dinitrophenol.

The NTO from the tank downstream of the IPOV during the pressure transducer failure was analyzed under LWO 701310 and the non-volatile residue (NVR) from this analysis was analyzed under LWO 701349 by FT-IR microscopy. The residue yielded a very close spectral match to picric acid (2,4,6-trinitrophenol), which is also a shock sensitive substance. The concentration of this substance in the NTO sample was estimated to be 5 mg/L. Most of the balance of the NVR is believed to be Krytox. The sample did not meet NASA Specification SE-S-0073, MON-3 due to the NVR level of 17 mg/L which exceeds the maximum of 10 mg/L. In addition, it did not meet NASA Specification SE-S-0073 because the >200 μm particle count was 3 per 100 mL which exceeded the maximum of 0 per 100 mL.

The inlet tube to the IPOV was flushed and 0.2 mg of residue was obtained. The residue had an FT-IR spectrum which was a good match with poly(dimethylsiloxane). This is basically the DC550 silicone oil without the phenyl groups. The oil that remained in the beaker after the NTO with silicone oil beaker test also matched with poly(dimethylsiloxane), indicating the loss of phenyl groups from the original oil.

Druck pressure transducers, with the isolation diaphragm and silicone oil, are used in several WSTF applications, including Hydrazine and MMH. Beaker tests were performed with the DC510® silicone oil in Hydrazine under LWO 701268 and in MMH under LWO 701266. No reaction was observed in either of these tests. A supply of DC550® silicone oil is on order. The beaker tests will be repeated and Test 15 will be performed when this DC550® silicone oil is received. The MMH and Hydrazine testing will be performed on LWO 701523 and 701524, respectively.

5.6 Metallurgical Analysis

The pressure port housing and the recovered section of the isolation diaphragm were submitted to the Materials Technology Group under LWO 701144 for analysis of the fracture surfaces. The diaphragm exhibited evidence of fatigue fractures, as shown in Figure 9, propagating from multiple initiation sites. Transgranular, partial penetration, secondary fractures were also observed on the diaphragm surface adjacent to and aligned with the through-thickness circumferential fracture, as shown in Figure 10.

The remainder of the diaphragm fracture surface was described as ductile overload rupture, as shown in Figure 11. No evidence was found that indicated the fatigue fractures were initiated by environmental degradation or a metallurgical discontinuity. X-ray microanalysis indicated the isolation diaphragm alloy was a molybdenum bearing austenitic stainless steel, consistent with the manufacturer's specification stating 316 stainless steel. The results of microstructural analysis and microhardness testing indicated that the isolation diaphragm material is in the annealed condition.

The transducer housing fracture, which occurred at the weld fusion zone, was found to be a ductile overload failure resulting from a single load application based on analysis of the pressure port end fracture surface, as shown in Figure 12.

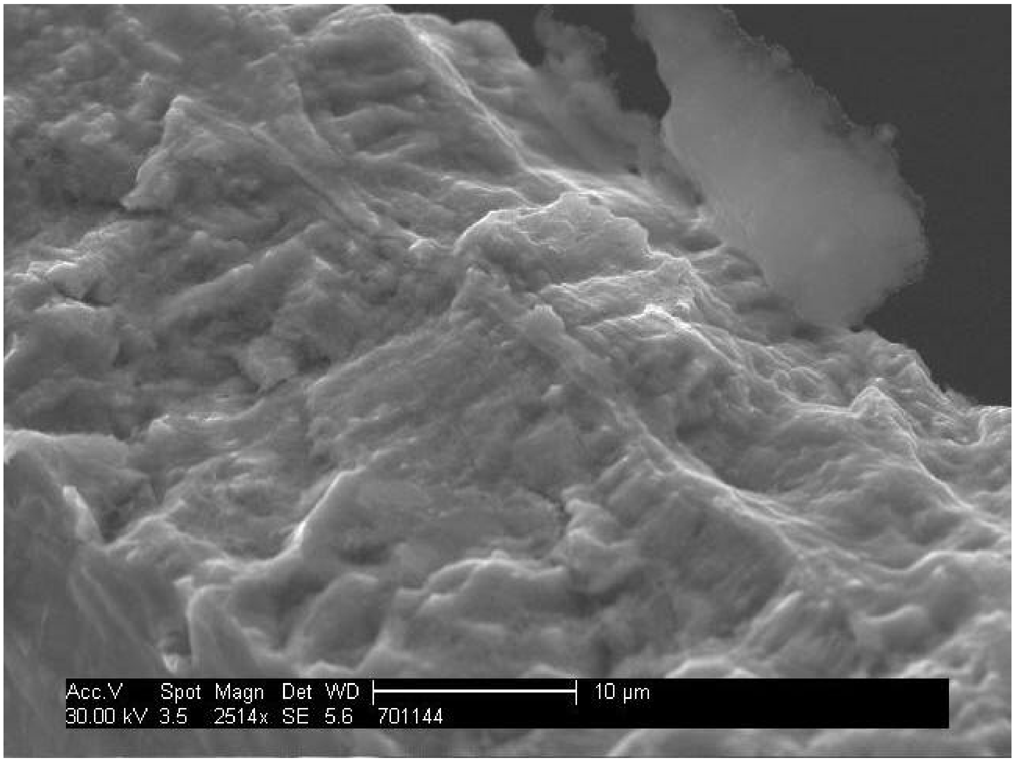


Figure 9: Scanning electron photomicrograph of crack arrest marks and fatigue striations observed on the circumferential diaphragm fracture.

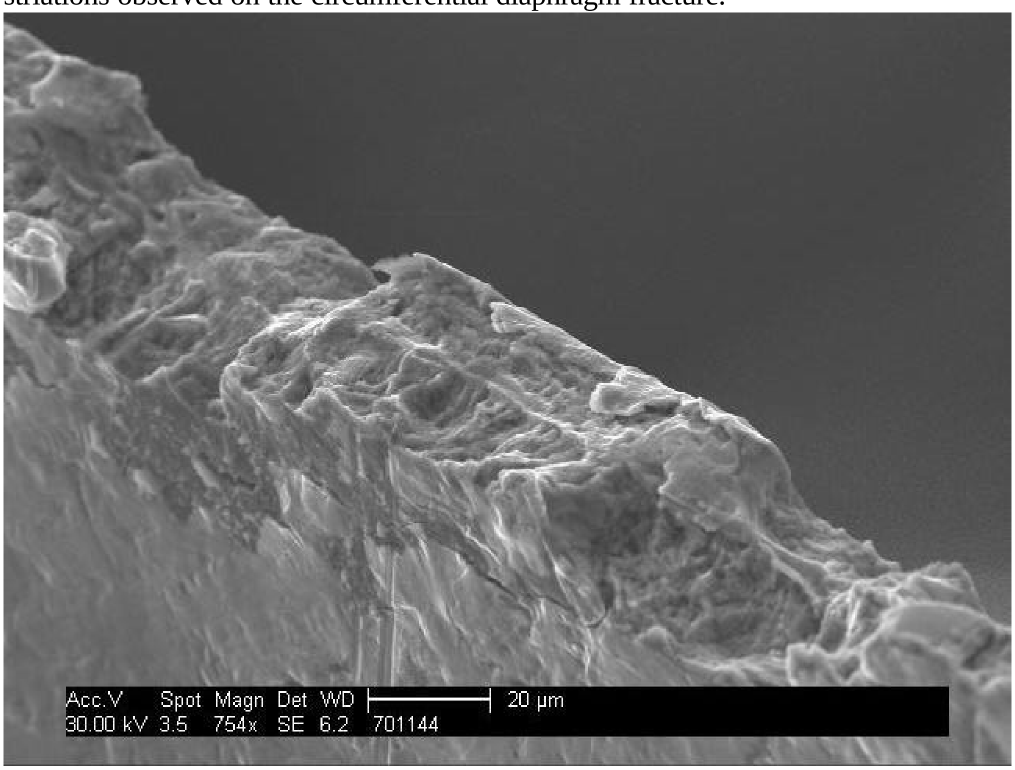


Figure 10: Scanning electron photomicrograph of crack arrest marks observed on the circumferential diaphragm fracture. Note also the transgranular, partial penetration, secondary fractures on the diaphragm surface adjacent to and aligned with the through-thickness circumferential fracture.

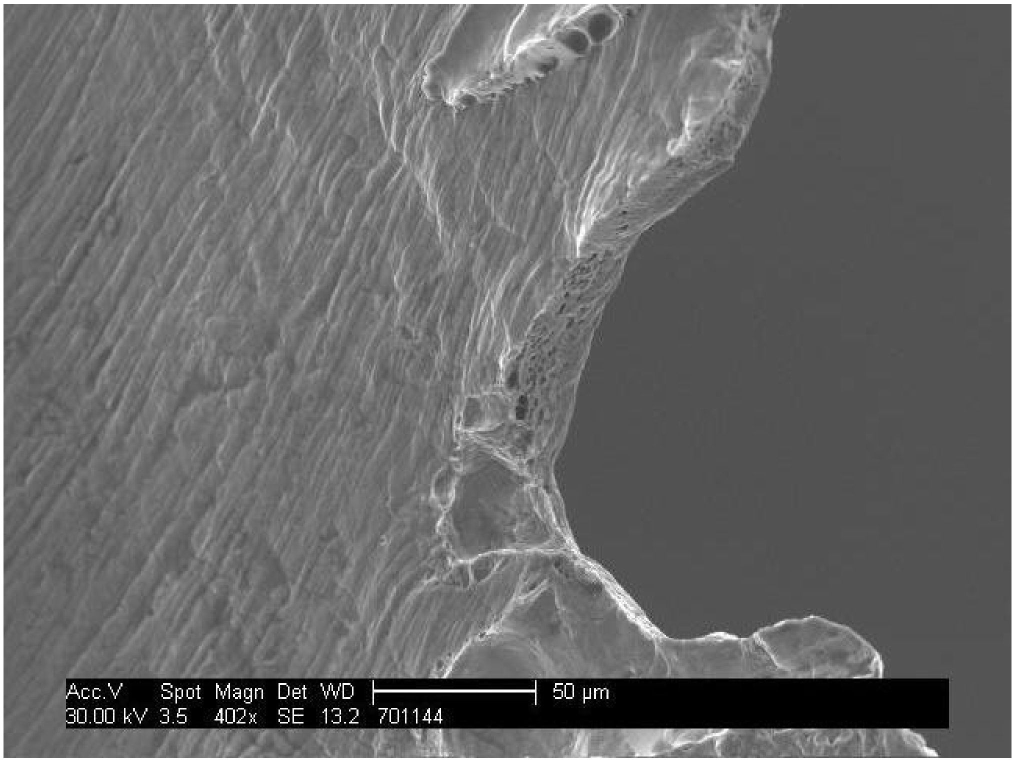


Figure 11: Scanning electron photomicrograph of elongated dimples observed on the circumferential diaphragm fracture at the EBW root, indicative of ductile behavior.

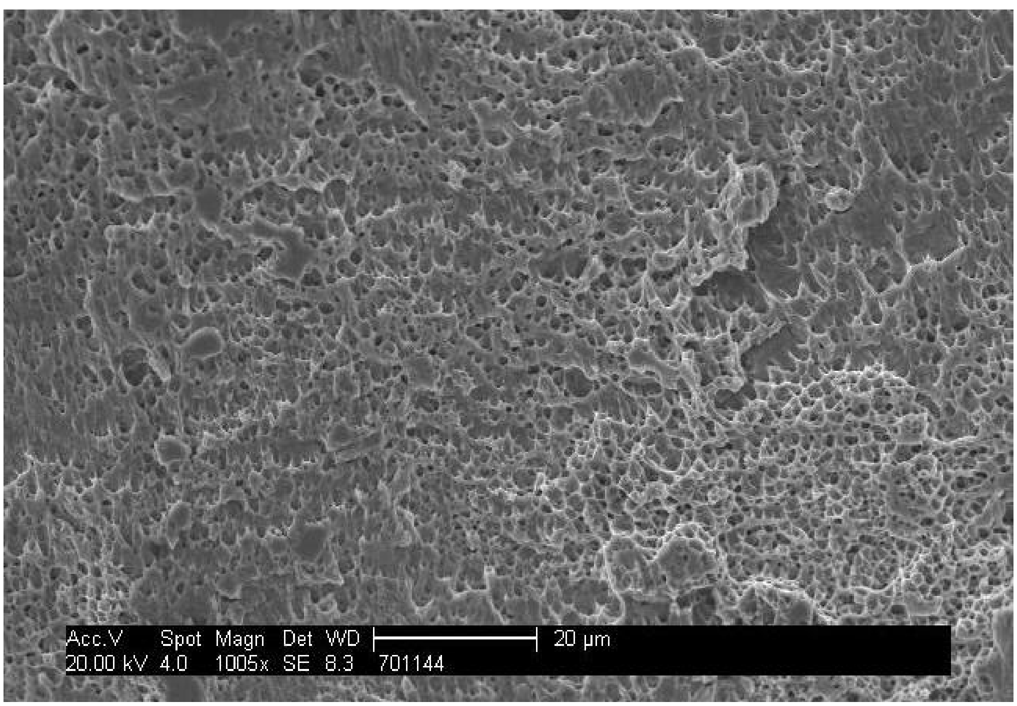


Figure 12: Scanning electron photomicrograph showing elongated dimples on the circumferential pressure port end fracture surface, indicative of a ductile-type overload

rupture.

5.7 Wind Corridor Review

NTO vapor was detected in the HPTA after the Test Cell 831 failure. Data of the wind direction and speed is available and was reviewed. The IPOV life cycle testing was being performed after hours. The wind corridor required to begin testing is the same as for standard operations but the wind corridor to continue testing was expanded. A TRR amendment for IPOV Life Cycle Testing (TRR 80S.0169.TRR.00A5.0831) approved the wind corridor modification for this test. The wind data for March 25, 2003 at 19:00 hours was reviewed and results of the wind direction at the three sensor locations is included on a facility plan view in Figure 13. The NTO release direction was included, based on the wind direction at this point being the same as at the wind sensor close to Test Cell 844, which is the controlling wind sensor for wind corridor decisions. The expanded wind corridor for the IPOV test was also included. Based on this information, the wind would have blown the NTO vapor over the northeast corner of the newly built HPTA cells 130, 131, and 132. The HVAC fresh air intake for this HPTA addition is on the east end of the addition and directly in the path of the NTO vapor release. Designing the HVAC system with the fresh air intake at the west end would have been preferable to avoid sucking propellant vapors into the HPTA. The HFTA wind corridor was further restricted to avoid potential propellant release over the corner of the HFTA or the north to south road east of the Control Room (Hazardous Fluids Test Area Safe Wind Corridor Memo of Record, April 23, 2003, 80P.0228.MEMO.0000.0000).

Future IPOV tests are planned with the wind corridor allowed in the TRR amendment, but the HPTA air handlers will be turned off prior to testing. Strict personnel access is required by this TRR amendment.

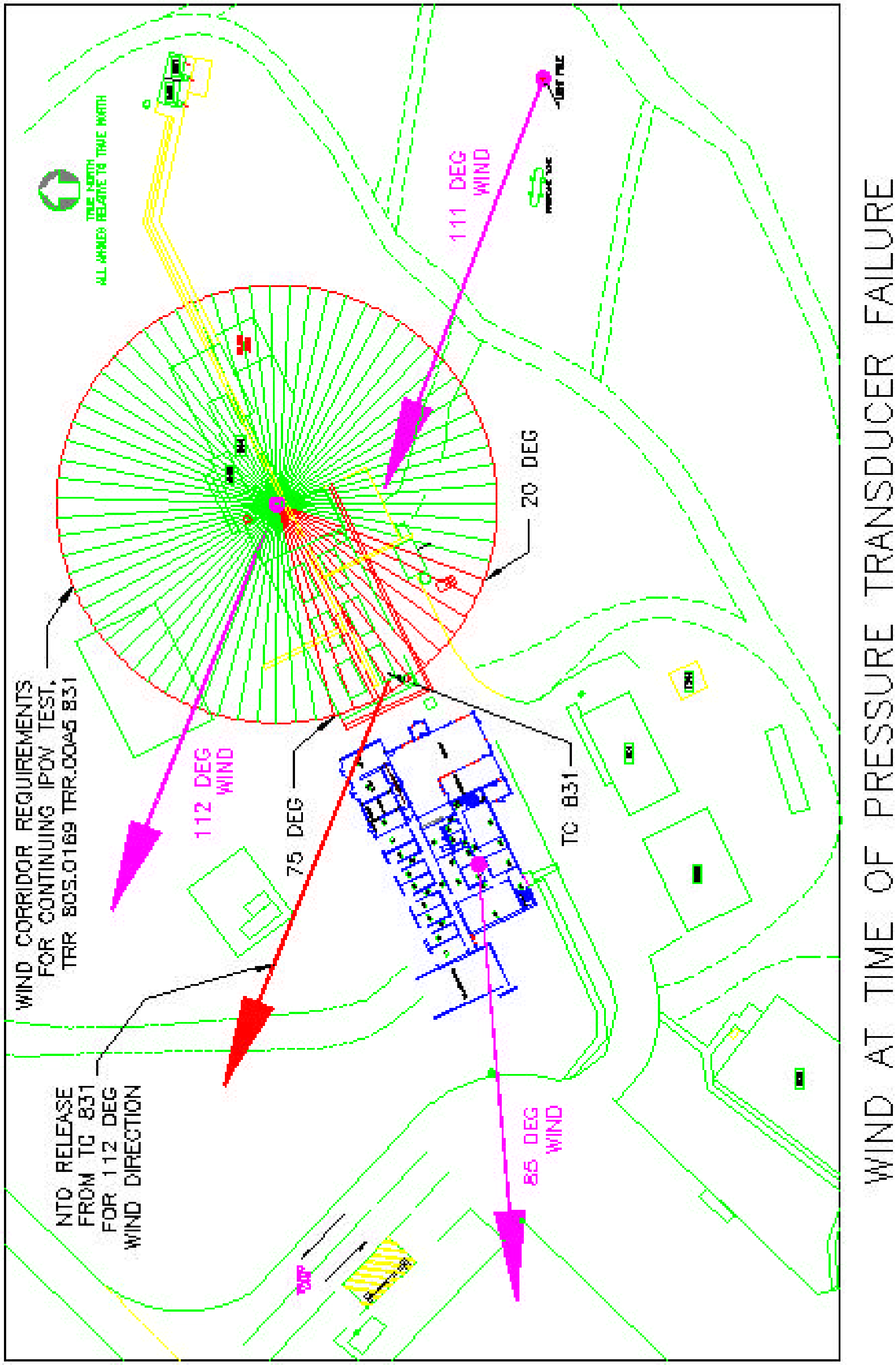


Figure 13: **Wind at Time of Pressure Transducer Failure**

6.0 Discussion and Conclusions

The pressure transducer failure in Test Cell 831 would require an internal pressure of ~12,700 psi based on failing the housing weld. If the pressure increased slowly from a chemical reaction in the volume of silicone oil between the isolation diaphragm and the silicon sensor, the isolation diaphragm would first deflect and block the pressure port passage allowing the pressure to build, but would then burst at approximately 4,000 psi and vent the pressure prior to failing the housing. If the pressure transducer failed due to severe "water hammer" from the IPOV inlet, the ¾-inch X 0.035-inch wall tubing would have yielded at ~3,400 psi, but no evidence of yielding was detected. The failure appears to be the result of high pressure in the housing with such a rapid pressure increase that venting through the inlet port does not prevent over-pressurization. Based on fatigue fractures in the diaphragm, diaphragm failure did occur prior to the single load application that burst the housing. The formation of shock-sensitive dinitrophenol from a reaction between the NTO and silicone oil would be anticipated if the isolation diaphragm fails. The rapid pressure fluctuations resulting in a pressure spike that goes from ~300 psi to ~1,380 and back to ~300 psi in 2.5 ms would appear to be a likely cause of detonating the dinitrophenol.

The cause of the pressure transducer output ceasing ~22 minutes prior to the failure is not certain, due to the damage that occurred to the hardware. The thin wires between the silicon sensor and the feed-through posts could have been broken or shorted from contact with the isolation diaphragm.

The following failure sequence appears reasonable based on analysis and information obtained during the investigation.

a) The dynamic response of the pressure transducer isolation diaphragm coupled with the silicone oil in the cavity behind the diaphragm to the IPOV inlet pressure results in increased diaphragm deflection and stress.
b) One or more fatigue fracture(s) propagate through the 0.002 in. thick 316 stainless steel isolation diaphragm.
c) Silicone oil seeps through the crack into the NTO and NTO seeps through the crack into the silicone oil cavity.
d) The silicone oil reacts with the NTO and dinitrophenol begins to accumulate as the reaction product. Some of the dinitrophenol forms and remains between the isolation diaphragm and the sensor while the rest is on the system side of the isolation diaphragm, dissolves in the NTO and circulates into the test system.
e) The diaphragm shorts or breaks the thin wires connecting the silicon sensor to the posts.
f) Impact from the IPOV inlet pressure cycle detonates the dinitrophenol that has formed between the isolation diaphragm and the silicon sensor. (Picric acid becomes increasingly impact sensitive as it dehydrates or becomes a powder. The effect of the various concentrations of dinitrophenol in silicone oil and NTO on impact sensitivity was not explored in this investigation. The presence of dinitrophenol and the detonation type failure were viewed as adequate evidence of the cause of failure.)
g) The detonation results in pressure that first ruptures the isolation diaphragm into the

pressure port and then bursts the pressure transducer at the housing weld connection.
h) The thrust from the gas release after burst drives the pressure transducer inlet port and electronics housings in opposite directions with the inlet port housing severely bending the ¼-inch connecting line and then failing the line at the maximum moment location close to the ¾-inch housing
i) NTO from the IPOV inlet side of the test system ejects from the opening left where the ¼-inch line was torn free for ~7.3 seconds until the test system is safed, releasing ~ 2.8 liters (~9 lbs) of NTO into the test cell.
j) The NTO vaporizes and is carried by the wind over the northeast corner of the HPTA with some of the NTO vapor entering the HPTA through the air handlers

Pressure transducers that are constructed with isolation diaphragms and a media non-compatible liquid fill are fairly common, produced by several manufacturers, and used in aerospace applications. These transducers may be used in numerous systems at other NASA locations and elsewhere. The lack of consistent, clear, objective information in the manufacturer's specifications regarding the details of construction of this design pressure transducer, including the presence of silicone oil between the isolation diaphragm and the sensor, makes the identification of the potential hazard difficult.

7.0 Recommendations

7.1 Discontinue use of pressure transducers that utilize an isolation diaphragm with silicone oil in WSTF NTO systems and systems which interface NTO systems. This includes many of the transducers supplied by Druck as well as other manufacturers. Specifications that state "silicon pressure sensor", "silicon technology", or list the strain gage type as "semi conductor" are probably this design. This design of pressure transducer should be ordered with oil that is compatible with the media. Druck has stated that the oil fill requirement should be stated on the Purchase Order (PO). Druck also stated that the PO could require factory etching the type of oil used on the transducer case to ease future identification.

7.2 Evaluate use of pressure transducers that utilize an isolation diaphragm with silicone oil in WSTF systems, such as oxygen, hydrazine, MMH, etc, based on a hazards analysis. The isolation diaphragm should be considered as a single point failure and the analysis should include consideration of media compatibility with silicone oil as well as system or hardware tolerance for silicone oil as a contaminant. (Initial review indicates that silicone oil filled pressure transducers are not suitable for oxygen systems.)

7.3 Emphasize the need to evaluate components for single fault tolerance. Due to sometimes limited information in component specification, this will often require discussions with the manufacturer or distributor to fully understand the product.

7.4 Reevaluate the HFTA wind corridor to ensure that a release at the end of the HFTA closest to the control room and HPTA is safely controlled. Note that the "Hazardous Fluids Test Area Safe Wind Corridor Memo of Record" (80P.0228.memo.0000.0000) was prepared by the HTSI supervisor and has been approved.

7.5 Initiate a Government – Industry Data Exchange Program (GIDEP) Alert for pressure transducers that are constructed with isolation diaphragms and a media non-compatible liquid fill.

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